Si 1/986

Department of the Interior
U.S. Geological Survey
EROS Data Center

National Mapping Program

NEWARK PUBLIC LIBRARY
JUL 8 1986
DEPOSITORY

SLAR
Side-Looking Airborne Radar

SLAR

Side-Looking Airborne Radar (SLAR) imagery is available from the U.S. Geological Survey (USGS) for selected project areas in the conterminous United States and Alaska. A valuable tool for geologic analysis, SLAR imagery can be useful for petroleum and mineral exploration, land use mapping, and ground-water studies. The ability to image large areas of the terrain for geologic structure and tectonic interpretation, along with a cloud-penetration capability that makes it possible to collect SLAR imagery when conventional aerial photographs are difficult to acquire, makes this imagery particularly valuable in earth-science investigations. The project areas are described inside.

Products

SLAR products available from the USGS include contact strip images, radar mosaics of most of the project areas, and digital data in the form of computer tapes for a few selected test areas. In addition, ancillary products, such as indexes (on paper, film, or microfiche), mission flight logs and final reports, and custom photographic products may also be available.

Strip Images

1:250,000 or 1:400,000 scale

Strip images are available as contact prints (both film and paper) at scales of either 1:250,000 or 1:400,000 (depending on the acquisition system used). These products are generally regarded as the best medium for interpretation because images in this form have the highest photographic resolution of the several available products.

Strip images are available as:

Paper Prints (PP)
Film Positives (FP)
Film Negatives (FN)

Mosaics

1:250,000 scale (1:100,000 scale for selected areas only)

Mosaics provide a synoptic view of the terrain, but because a mosaic is a third-generation photographic product, it may be of somewhat lesser resolution than photographic reproductions of the original strip images. In addition, shadow differences, which are produced by the change in depression angle across the radar swath, occur across mosaic junction lines between adjoining strips. These differences in length of shadow can result in misinterpretation of apparent terrain relief where no differences actually exist. The 1:100,000-scale mosaic products are enlarged from one quarter (NE, SE, SW, or NW) of the 1:250,000-scale mosaics.

Ugashik, Alaska, August 1980, Southeast Look

1:250,000- and 1:100,000-scale mosaics are available as:

Paper Prints (PP)
Film Positives (FP)
Film Negatives (FN)

Ancillary and Custom Products

Ancillary products such as flightline indexes (both paper and microfiche), 1:1,000,000-scale strip image index mosaics (for selected areas), and mission flight logs and final reports are available. In addition, custom products such as special enlargements may be ordered. Prices for both ancillary and custom products can be obtained from the EROS Data Center upon request.

SLAR Microfiche Reference System

Users interested in acquiring SLAR materials from the USGS can review the data by viewing the SLAR Microfiche Reference System (available from the EROS Data Center). All SLAR coverage areas are displayed on the microfiche for the users' convenience in choosing either strip or mosaic data of an area of interest. These microfiche provide ordering instructions for both strip images and mosaic products.

On the next two pages are a map showing the SLAR project areas and a table summarizing available SLAR data by project area, including flight parameters, available products, and microfiche titles. Titles shown are the names of the 1:1,000,000-scale maps used to plot the SLAR coverage and do not refer to SLAR mosaic names. The numbers shown in parentheses after the microfiche titles are the number of individual microfiche depicting coverage of the specific project area. For example, the NA project area shows nine (9) Barrow microfiche. Multiple microfiche of the Barrow area of Alaska are necessary because of the dual look and stereo overlap of all of the data acquired in the NA project area.

Ordering Procedure

See attached order form inside for prices. To place orders and obtain additional information regarding technical details and ancillary products, contact:

U.S. Geological Survey
EROS Data Center
User Services Section
Sioux Falls, SD 57198
(605) 594-6151; FTS 784-7151

READEX FICHE

I 19.80:

Summary of SLAR Project Areas and Data

All data are X-band synthetic aperture radar (horizontally transmitted, horizontally received) acquired in both near and far range unless otherwise noted. In general, location names refer to USGS 1:250,000-scale (usually 1° × 2°) topographic map quadrangles. Near-range mosaics are available for each project area unless otherwise noted. Abbreviation TBD — To be done.

PROJECT AREAS

AA

Location: Adak, Amukta, Atka, Attu, Gareloi Island, Kiska, Rat Island, Samalga Island, Seguam, Umnak, Unalaska, and Unimak
Date: August, September 1982
Look Direction(s): Variable
Scale: 1:400,000 strip imagery, 1:250,000 screenless prints of mosaics
Microfiche: Attu Island (1), Andreanof Island (1), Cold Bay (1)
Comments: Near-range data only

AD

Location: Binghamton, Lake Champlain, Ogdensburg, and Utica
Date: May, July 1984
Look Direction: West
Scale: 1:250,000 strip imagery, 1:100,000 and 1:250,000 mosaics (both near and far range); 1:1,000,000 index mosaics
Microfiche: TBD
Comments: The eastern third of the Lake Champlain quadrangle was also acquired for the NE project area.

AP

Location: Afognak, Bristol Bay, Chignik, Cold Bay, False Pass, Karluk, Mt. Katmai, Naknek, Port Moller, Stepovak Bay, Unimak, Ugashik, and Sutwik Island
Date: August, November 1980
Look Direction: Variable
Scale: 1:400,000 strip imagery (also 1:250,000 for a selected test area); 1:250,000 mosaics; 1:1,000,000 index mosaics
Microfiche: Kodiak (1), Bristol Bay (1), Cold Bay (1)
Comments: Bristol Bay, Karluk, and Ugashik were multi-look, both real and synthetic aperture, both 1:400,000- and 1:250,000-scale strip imagery available of this area.

CA

Location: Charlottesville, Cumberland, Harrisburg, Pittsburgh, and Roanoke
Date: September 1982
Look Direction: North or NW
Scale: 1:400,000 strip imagery; 1:250,000 mosaics (both near and far range); 1:1,000,000
Microfiche: Hudson River (1), Chesapeake Bay (1), Lake Erie (1), Blue Ridge (1)

CC

Location: Canton, Cleveland
Date: October 1984
Look Direction: West
Scale: 1:400,000 strip imagery; 1:250,000 mosaics; 1:1,000,000 index mosaics
Microfiche: TBD

EP

Location: Baltimore, Richmond, Washington, and the Virginia portion of Norfolk (only strip data are available for this portion of Norfolk)
Date: May, August 1984
Look Direction: West
Scale: 1:250,000 strip imagery; 1:100,000 and 1:250,000 mosaics (both near and far range); and 1:1,000,000 index mosaics
Microfiche: TBD
Comments: Data for approximately 2,300 square miles of the Washington and Richmond quadrangles were also acquired in September 1982 with an east look direction; 1:400,000 strip data (near and far range) and computer-compatible tapes (near-range data only) are available for this test site.

JO

Location: Joplin
Date: November 1984
Look Direction: West
Scale: 1:400,000 strip imagery; 1:250,000 mosaic; and 1:1,000,000 index mosaic
Microfiche: TBD

LE

Location: Leadville
Date: Summer 1985
Look Directions: NE and SE
Scale: 1:400,000 strip imagery; 1:250,000 mosaics (two look directions); and 1:1,000,000 index mosaics
Microfiche: TBD

LM

Location: Ardmore, Little Rock, McAlester
Date: November, December 1984
Look Direction: NW
Scale: 1:400,000 strip imagery; 1:250,000 mosaics, and 1:1,000,000 index mosaics
Microfiche: TBD

Order Form

Project Area	Quadrangle(s)	Scale	PP FP FN	Roll	Frame/ Strip	No. of Copies	Unit Price	Total Price
							Total Cost	

	Mosaic		Strip
	1:250,000 scale	1:100,000 scale (where available)	
Paper Print (PP)	$ 85 each	$60 each	$30 each
Film Positive (FP)	$100 each	$85 each	$35 each
Film Negative (FN)	$100 each	$85 each	$35 each

D

Name (first, middle initial, last)	Date
Company/Agency	Phone (Bus.)
Address	Phone (Res.)
City, State, and Zip	Purchase Order No.
Ship To:	Control No. (if known)

Prepayment is required.

Return Completed Form To:
U.S. Geological Survey, EROS Data Center
User Services Section, Sioux Falls, SD 57198
605-594-6151: FTS 784-7151

Payment made by:

Check, money order ☐
Purchase order ☐
Government account ☐

NA **Location:** DeLong Mtn., Howard Pass, Ikpikpuk River, Lookout Ridge, Misheguk Mtn., Point Hope, Point Lay, Utukok River
Date: August, September 1980; October 1981
Look Directions: North and South
Scale: 1:250,000 strip imagery; 1:250,000 mosaics (two look directions); and 1:1,000,000 index mosaics
Microfiche: Barrow (9), Umiat (l), Kodiak (l), Bristol Bay (l)
Comments: Real aperture data only.

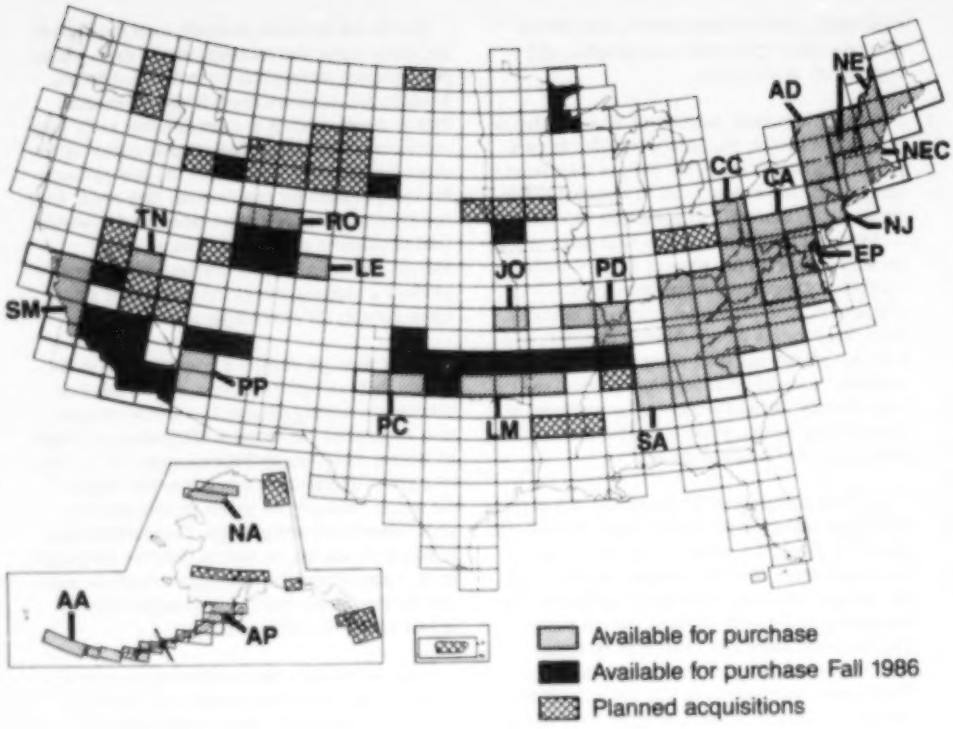
NE **Location:** Glens Falls, Lake Champlain, Lewiston, and Sherbrooke
Date: September 1982
Look Direction: West
Scale: 1:400,000 strip imagery; 1:100,000 and 1:250,000 mosaics; 1:1,000,000 index mosaic
Microfiche: Ottawa (l), Quebec (l), Hudson River (l), Boston (l)
Comments: Only the U.S. part of the Sherbrooke quad and only the eastern third of Lake Champlain quad are available, but the entire area of the Lake Champlain quad was acquired for the AD project area.

NEC **Location:** Albany, Bangor, Bath, Boston, Eastport, Hartford, Newark, New York, Portland, Providence, and Scranton
Date: May, August 1984
Look Direction: East
Scale: 1:250,000 strip imagery; 1:100,000 and 1:250,000 mosaics (both near and far range); and 1:1,000,000 index mosaics
Microfiche: TBD

NJ **Location:** Approximately a 6 × 100-mile rectangle in the Newark and Wilmington quadrangles, flown over the exposed Woodbury Clay in New Jersey
Date: September 1982
Look Directions: NE and SE
Scale: 1:400,000 strip imagery
Microfiche: Chesapeake Bay (l), Hudson River (l)

PC **Location:** Plainview, east half of Clovis quadrangle (Texas only)
Date: November, December 1984
Look Direction: North
Scale: 1:400,000 strip imagery; 1:250,000 mosaics, and 1:1,000,000 index mosaics
Microfiche: TBD

PD **Location:** Dyersburg, Paducah, Rolla
Date: November 1984
Look Direction: West
Scale: 1:400,000 strip imagery; 1:250,000 mosaics, and 1:1,000,000 index mosaics
Microfiche: TBD



PP **Location:** Phoenix, Prescott
Date: October 1984
Look Direction: East
Scale: 1:400,000 strip imagery; 1:250,000 mosaics; and 1:1,000,000 index mosaics
Microfiche: TBD

RO **Location:** Ogden, Rock Springs
Date: Summer 1985
Look Direction: West
Scale: 1:400,000 strip imagery; 1:250,000 mosaics, and 1:1,000,000 index mosaics
Microfiche: TBD

SA **Location:** Atlanta, Birmingham, Bluefield, Charleston, Charlotte, Chattanooga, Clarksburg, Corbin, Gadsden, Greensboro, Greenville, Huntington, Jenkins, Johnson City, Knoxville, Louisville, Raleigh, Rome, Winchester, and Winston-Salem
Date: May, July 1984
Look Direction: Variable
Scale: 1:250,000 strip imagery; 1:100,000 and 1:250,000 mosaics (both near and far range); 1:1,000,000 index mosaics
Microfiche: TBD
Comments: Computer-compatible tapes are available for several small test sites in the Greensboro, Raleigh, Chattanooga, and Rome quadrangles. X-, L-, and C-band data, both like- and cross-polarized, are available for small test sites in the Greensboro and Raleigh quadrangles. Computer-compatible tapes are also available for some of these sites.

SM **Location:** Monterey, San Francisco, San Jose, San Luis Obispo, and Santa Maria (mainland only)
Date: December 1984
Look Direction: East
Scale: 1:400,000 strip imagery; 1:250,000 mosaics, and 1:1,000,000 index mosaics
Microfiche: TBD
Comment: Computer-compatible tapes are available for the entire project area.

TN **Location:** Tonopah
Date: September, October 1982
Look Direction: S 10° W, and N 56° W (partial coverage)
Scale: 1:400,000 strip imagery; and 1:250,000 mosaics
Microfiche: Mount Whitney (l)

A PRIMER ON SIDE-LOOKING AIRBORNE RADAR

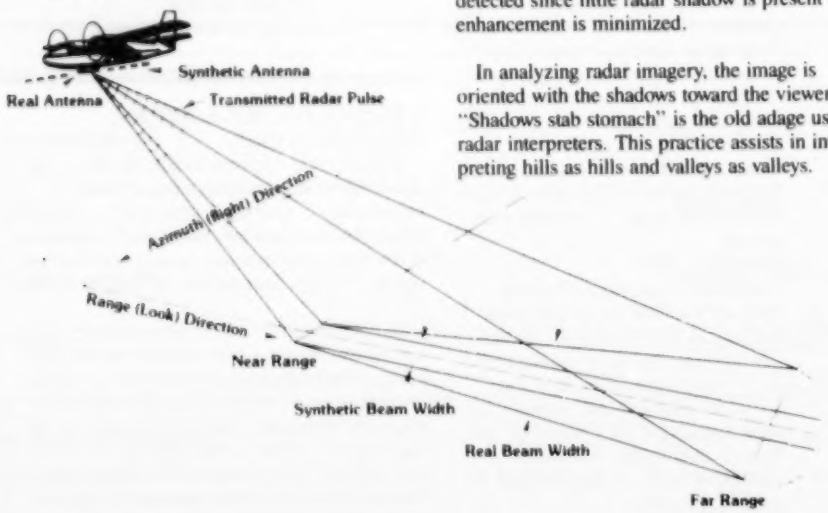
Side-Looking Airborne Radar (SLAR) images are so different from other types of remotely sensed data, in both mode of acquisition and techniques for interpretation, that a short explanation of important concepts and the use of this technology in the earth sciences will aid potential users.

SLAR is an electronic image-producing system that derives its name from the fact that the radar beam is transmitted perpendicular to the side of the aircraft acquiring the data. The result is an obliquely illuminated view of the terrain, a view that enhances subtle surface features and facilitates geologic interpretation. This enhancing characteristic is one of the reasons why SLAR imagery is so useful to earth resource scientists and managers involved in mineral and energy

exploration, earth hazards studies, and diverse other geologic, hydrologic, cartographic, and engineering applications.

Another important property of SLAR is that it is an active sensor; the system provides its own source of illumination in the form of microwave energy, and thus imagery can be obtained either day or night. Since SLAR penetrates most clouds, it can be used to prepare image-base maps of perpetually cloud-covered areas of the world where collecting conventional aerial photographs is impractical, such as the rain forests of Brazil or along the Aleutian Arc of Alaska. However, precise topographic mapping using SLAR data is not currently practical because of geometric distortions inherent in radar imagery. For example, in mountainous terrain, positional error may be as much as several hundred meters.

Since the radar signal is transmitted at a depression angle below the horizontal plane in which the aircraft is flying, the signal strikes the terrain at an oblique angle, and the surficial expression of the geologic structure may thus be enhanced. The topographic expression of some surface features, such as subtle faults and folds, may be more clearly seen on the radar image than on conventional aerial photographs or satellite images. For example, a depression angle ranging from approximately 10° to 40° across the imaged swath is used for many earth science applications. The change in depression angle across the imaged swath (a swath having a width of approximately 40 km is used by some commercially available systems) results in features nearer the flightline having shorter radar shadows than features of equal elevation farther from the flightline. Since SLAR is an active sensor, when a radar beam strikes a sufficiently elevated terrain feature, a radar shadow is cast by the feature; this is an area of no data return. The gradual change of shadow length across the **range**-perpendicular to the flight path (and to the width of the image swath) has resulted in the convention of designating the parts of the radar swath: **near range,** or that half of the radar swath nearest the flightline; and **far range,** that half of the swath farthest from the flightline. **Azimuth** is the term used to describe the direction of the radar image parallel to the flightline, or the bearing of the flightline itself.



The SLAR products generally used for analysis are image strips and mosaics. Image strips are the photographic representations of the SLAR data. Usually, the strips are much longer in azimuth than in range, since it is more efficient to fly long continuous flightlines. Photographic copies of the strips are generally regarded as the best products for interpretation for two reasons: they are at least one photographic generation closer to the original than subsequent products such as an image mosaic, and strips are not cosmetically altered to produce a pleasing composite image as is sometimes done in the mosaicking process.

SLAR mosaics provide a synoptic view of the terrain, but both the resolution and information content are slightly degraded in mosaic preparation. In addition, in mosaics, differences in length of shadow from terrain features, produced by the changes in depression angle across the range of the image swath, occur across mosaic junction lines between adjoining strips. These differences in length of shadow, as well as possible variations in the radar returns from similar features in near and far range, can result in misinterpretation of terrain and surface characteristics.

It should be noted that positive transparencies of both image strips and mosaics are generally considered superior to photographic paper for interpretation, because the film has a greater density range and therefore contains more information. Because image strips have an overlap of about 60 percent, both near- and far-range mosaics can be prepared by laying the respective halves of adjacent SLAR image strips side by side. These two SLAR presentations complement each other since the near-range data have less radar shadowing while the far-range data have more surface enhancement.

The look direction of a radar image refers to the illumination direction; for example, west looking. The choice of mission design parameters such as look direction and depression angle is usually based on an analysis of the geologic structure of the area. The parameters are then chosen to assure optimum data acquisition for the goals of the study. For example, linear structures such as faults that are parallel or nearly parallel to the range, or look, direction may not be easily detected since little radar shadow is present and enhancement is minimized.

In analyzing radar imagery, the image is oriented with the shadows toward the viewer. "Shadows stab stomach" is the old adage used by radar interpreters. This practice assists in interpreting hills as hills and valleys as valleys.

Most commercially available SLAR systems operate in the X-band at frequencies of 12.0–8.0 gigahertz (GHz or billions of cycles per second) and wavelengths of 2.4–3.8 centimeters (cm). Usually these systems transmit and receive horizontally polarized signals (HH). For some purposes it is advantageous to acquire data with an experimental SLAR radar system that operates at more than one frequency and utilizes a vertically polarized (either transmitted or received or both) radar beam; radar data can be like (HH or VV) or cross (HV or VH) polarized depending on the antenna design. In addition to X-band, other frequencies in current use are C-band at 8.0–4.0 GHz and 3.8–7.6 cm, and L-band at 2.0–1.0 GHz and 15.0–30.0 cm.

SLAR is a generic term for two distinctly different technologies: real aperture radar, also known as "brute force"; and synthetic aperture radar (SAR) also known as coherent radar.

In a real-aperture system, a fan-shaped beam is transmitted, reflected by the surface, received, processed, and recorded as a line on the image. Although the angle of the transmitted radar beam is constant (for example, 0.45°), the width of the beam is narrower in the near range than in the far range, and thus the resolution is better in the near than in the far range. Resolution in the range direction is constant. Using our example, portions of the data in the near range would have a resolution of approximately 30 × 75 m in range and azimuth respectively, while portions of the far range would have a resolution of approximately 30 × 150 m. It must be noted that resolution and detectability are not the same thing with radar; objects of less than 1 meter size may be routinely detected because of the strong radar return of some features. Bright radar returns may be caused by corner-reflector geometry or electrical resonance effects.

Synthetic aperture radar has constant range and azimuth resolutions throughout the image. This constancy is accomplished primarily by using more detailed information processing of the returned signal, thus simulating a longer antenna. A longer antenna produces a narrower radar beam, improving the resolution. Presently available commercial synthetic-aperture systems have resolutions of approximately 10 × 10 m or better.

SLAR data are particularly valuable when used in conjunction with traditional earth-science data, as well as with other remotely sensed data. Scientists from private industry, government, and universities have effectively used SLAR all over the world to aid in mapping previously known and undiscovered geologic features that have contributed to the discovery of new mineral and energy reserves. More than 25 million square km of SLAR data have been gathered for government and private sector interests in many countries, including Brazil, Colombia, Ecuador, Guinea, Indonesia, Japan, Nigeria, Peru, and the United States.